

Supplementary Materials

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Supplementary Figure 2. Annual trends of publications and citations focusing on the ethics of AI in ophthalmology.

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Supplementary Note 1. Synonyms merged in VOSviewer

Supplementary Table 1. Comparison of this paper with existing literatures focusing on the ethics of AI in ophthalmology.

Title	Quantitative analysis	Ethical issues	Standards/norms/guideline/consensus/legislation	Technological solution	Future direction/ Strategies
Novel technical and privacy-preserving technology for artificial intelligence in ophthalmology ¹	No	No	No	1. FL 2. GANs 3. Blockchain	1. Using blockchain, FL and GANs) 2. Collaborative AI model training from multiple parties 3. Developing robust defense techniques with improved efficiency
Foundational Considerations for Artificial Intelligence Using Ophthalmic Images ²	No	1. Nonmaleficence (“do no harm”, patient benefit, improved clinical outcomes) 2. Autonomy (patient decides; patient in control of their healthcare) 3. Equity (absence of bias, fairness in distribution, rights and benefits of groups)	Guidelines of three ethical principles (nonmaleficence, autonomy and equality) in the design, validation, and implementation of AI systems	1. Three forms of considerations to assess for the nonmaleficence AI design: explainability, transparency and validity 2. Validation study design, reference standards and minimal acceptable criteria for validation prospective monitoring protocols for postmarket monitoring of AI Systems and nonmaleficence 3. Two important considerations of autonomy of the patient: auditable processes and security controls aid in the use of patient-derived data; determination of responsible subject of liability for AI system malfunction 4. Population-achieved sensitivity/access-corrected sensitivity used to assess equality in population	1. The considerations in this article for the design, validation, and implementation of AI systems are a useful first step in the development of a bioethically sound foundation 2. Considerations of FPOAI’s future consensus statements and cooperation among all stakeholders in the health care system will guide development and use of clinical AI, helping to make fundamental improvements in accessibility and quality of health care, to decrease disparities, and to lower the overall cost of health care.
Trustworthy AI: Closing the gap between development and integration of AI systems in ophthalmic practice ³	No	1. The importance of trustworthy AI for the development and integration of responsible systems in ophthalmolog	Generally accepted protocols and consensuses for the various stages(definition of intended use, data collection, data labelling, training and retrospective validation, prospective validation,	Proposed solutions and considerations for the various stages(definition of intended use, data collection, data labelling, training and retrospective validation, prospective validation, regulation) of the design pipeline of a trustworthy ophthalmic AI system	In order to realize trustworthy AI, A collaborative approach to determine the responsibility the different stakeholders are taken along the AI design pipeline, from the definition of the intended use to post-market surveillance after regulatory approval.

		2. Illustrating the stages in the AI design pipeline as well as the stakeholders involved in AI for ophthalmic care, showing the identified aspects or challenges to address for each stage in order to generate trustworthy AI systems in ophthalmology.	regulation) of the design pipeline of a trustworthy ophthalmic AI system		
Towards effective data sharing in ophthalmology: data standardization and data privacy ⁴	No	1. Data standardization 2. Data privacy	Data standards for interoperability in health information technology: 1. Format or structure of data: DICOM/OMOP CDM 2. Communication protocol: FHIR 3. Minimum required elements: USCDI 4. Clinical coding nomenclature: ICD-10	1. Blockchain 2. Federated analysis 3. Synthetic data(GAN) 4. Differential privacy	1. Expand ophthalmic data standards based on awareness and implementation of current standards 2. Ensuring data privacy to promote data sharing and balancing data privacy with data sharing
The Ethical and Societal Considerations for the Rise of Artificial Intelligence and Big Data in Ophthalmology ⁵	No	1. Bias and fairness 2. Privacy	No	1. Addressing training data imbalance through proper patient recruitment, model change or fine-tuned model 2. FL 3. Differential privacy	1. curate AI/ML ready data based on ethical principles 2. Multi-disciplinary teams comprised of physicians, computer scientists and ethicists 3. Considering ethical issues throughout the entire lifecycle
Ethics of Artificial	No	1. Machine training ethics	1. Standardization 2. Quality assurance	1. Data protection methods 2. Solutions for potential Biases	1. multifactorial solutions of different ethical problems 2. universal standardization for ethical and regulatory

Intelligence in Medicine and Ophthalmology ⁶		- Machine accuracy ethics - Patient-related ethics - Physician-related ethics - Shared ethics - Role of regulator (For medical science)	- Marketing approval - Licensing and ethical standards (For medical science)	- Embedding informed consent into algorithms and contextualized solutions for confidentiality - legislative and regulatory laws for liability (For medical science)	considerations (For medical science)
Impact and Challenges of Integrating Artificial Intelligence and Telemedicine into Clinical Ophthalmology ⁷	No	- Trust and public perception - Data privacy and liability - Medico-Legal issues - Maintaining patient safety - Digital exclusion(health care inequalities)	- European Union: White Paper: On Artificial Intelligence - GDPR - Clinical trials and prediction models in AI (ex: CONSORT-AI, SPIRIT-AI) - WHO Guideline: Recommendations on digital interventions for health system strengthening	- Popularizing research and guidelines for increasing human trust in AI - Principles, laws, and techniques that uphold patient safety and rights - Strengthen infrastructure and lower financial barriers to reduce health care imbalances	- Organizational leadership - Failsafe modes - Technological advances - Clinician engagement - Patient engagement
Applications of interpretability in deep learning models for ophthalmology ⁸	No	- Complex models lack understanding and trust - Non-transparent 'Black-box' models	No	- Model-centric interpretability strategies: (1) Surrogates: LIME/Global surrogates (2) Network visualization: TCAV/CAM/ DeConvNet - Data-centric interpretability strategies: (1) Examples: Adversarial examples/Counterfactuals (2) Attribution methods: Gradients/Occlusion/Attention mechanisms	- Explicit definition of interpretability - Establishing accepted frameworks to evaluate quality of interpretability methods and efficacy
Controversies in artificial intelligence ⁹	No	- lack of explainability - limited generalizability - potential biases - protection of patient confidentiality	No	- The occlusion test - saliency maps (heat maps) generation by techniques such as class activation mapping - Other visualization methods to understand the decision-making process - Prospective, multisite trials - Synthetic Minority Over-Sample Technique - GANs	- Improving the explainability, the extent to which the internal mechanics of a deep learning system can be explained in medical terms - High-quality, robustly designed, generalizable studies that are validated by prospectively collected - using multiethnic, multiracial populations for testing to eliminate potential biases in the training and validation of artificial intelligence algorithms

		y in large-scale data transfer			
Protecting Data Privacy in the Age of AI-Enabled Ophthalmology ¹⁰	No	1. Ethical considerations 2. Data protection and privacy 3. Data sharing 4. Models for consent	1. HIPAA 2. GDPR	6. Differential privacy 7. Federated learning (FL) 8. Generative adversarial networks (GANs) (For medical science)	4. Creating new regulations governing privacy 5. Seeking balance between innovation and privacy 6. Education of patients and public
This paper	Yes	9 ethical themes are identified and ranked according to their prominence, alongside preferences in ethical focus across ophthalmic data modalities.	1. Multi-countries/institutions guidelines. 2. Lack of specific normative documents for ethics of AI in ophthalmology.	1. Employing existing ethical technologies in the development of ophthalmic screening AI is the main resolution strategy. 2. Technologies specifically designed to resolve ethical issues are scarce.	1. Interdisciplinary and international collaboration among ophthalmology, AI, and ethics. 2. Compliant data usage according to different ethical focus. 3. Development of specific ethical technologies for ophthalmic AI. 4. Refinement of normative documents tailored to ethics of AI in ophthalmology.

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Supplementary Table 2. Search terms for AI Ethics Topics in Medicine and Its Sub-disciplines (Database: WOSCC).

Categories	Keywords
Ethics/Morality*	TS=(“ethic*” OR “moral” OR “morality” OR “transparenc*” OR “fairness” OR “justice” OR “equality” OR “non-maleficence” OR “responsib*” OR “accountab*” OR “privacy*” OR “confidential*” OR “beneficence” OR “autonomy” OR “trust” OR “dignity*” OR “sustainab*” OR “solidar*”) OR TI=(“ethic*” OR “moral” OR “morality” OR “transparenc*” OR “fairness” OR “justice” OR “equality” OR “non-maleficence” OR “responsib*” OR “accountab*” OR “privacy*” OR “confidential*” OR “beneficence” OR “autonomy” OR “trust” OR “dignity*” OR “sustainab*” OR “solidar*”) OR AB=(“ethic*” OR “moral” OR “morality” OR “transparenc*” OR “fairness” OR “justice” OR “equality” OR “non-maleficence” OR “responsib*” OR “accountab*” OR “privacy*” OR “confidential*” OR “beneficence” OR “autonomy” OR “trust” OR “dignity*” OR “sustainab*” OR “solidar*”)
Artificial Intelligence*	((TS=("artificial intelligence" OR "artificial neural network" OR "machine intelligence" OR "machine learning" OR "deep learning" OR "deep learn*" OR "natural language process" OR "robotic*" OR "computer vision*")) OR TI=("artificial intelligence" OR "artificial neural network" OR "machine intelligence" OR "machine learning" OR "deep learning" OR "deep learn*" OR "natural language process" OR "robotic*" OR "computer vision*")) OR AB=("artificial intelligence" OR "artificial neural network" OR "machine intelligence" OR "machine learning" OR "deep learning" OR "deep learn*" OR "natural language process" OR "robotic*" OR "computer vision*"))
Medicine & Healthcare	(TS=(“medic*” OR “health*” OR “healthcare” OR “disease*” OR “illness” OR “health-related” OR “treatment” OR “therapy”) OR TI=(“medic*” OR “health*” OR “healthcare” OR “disease*” OR “illness” OR “health-related” OR “treatment” OR “therapy”) OR AB=(“medic*” OR “health*” OR “healthcare” OR “disease*” OR “illness” OR “health-related” OR “treatment” OR “therapy”))
Cardiovasology	(TS=(“cardiovascular*” OR “cardiac*” OR “cardiologic*” OR “cardiopathy” OR “heart disease” OR “hypertension” OR “coronary artery disease” OR “myocardial infarction” OR “heart failure” OR “arrhythmia” OR “cardiomyopathy” OR “atherosclerosis” OR “artery disease” OR “venous disease” OR “embolism”) OR TI=(“cardiovascular*” OR “cardiac*” OR “cardiologic*” OR “cardiopathy” OR “heart disease” OR “hypertension” OR “coronary artery disease” OR “myocardial infarction” OR “heart failure” OR “arrhythmia” OR “cardiomyopathy” OR “atherosclerosis” OR “artery disease” OR “venous disease” OR “embolism”) OR AB=(“cardiovascular*” OR “cardiac*” OR “cardiologic*” OR “cardiopathy” OR “heart disease” OR “hypertension” OR “coronary artery disease” OR “myocardial infarction” OR “heart failure” OR “arrhythmia” OR “cardiomyopathy” OR “atherosclerosis” OR “artery disease” OR “venous disease” OR “embolism”))
Respirology	(TS=(“respiratory*” OR “pulmonary*” OR “lung*” OR “breathing problem” OR “asthma*” OR “pneumonia” OR “bronchitis” OR “emphysema” OR “chronic obstructive pulmonary disease” OR “pleurisy” OR “acute respiratory distress syndrome” OR “pleurisy” OR “pulmonary fibrosis” OR “lung abscess”) OR TI=(“respiratory*” OR “pulmonary*” OR “lung*” OR “breathing problem” OR “asthma*” OR “pneumonia” OR “bronchitis” OR “emphysema” OR “chronic obstructive pulmonary disease” OR “pleurisy” OR “acute respiratory distress syndrome” OR “pleurisy” OR “pulmonary fibrosis” OR “lung abscess”) OR AB=(“respiratory*” OR “pulmonary*” OR “lung*” OR “breathing problem” OR “asthma*” OR “pneumonia” OR “bronchitis” OR “emphysema” OR “chronic obstructive pulmonary disease” OR “pleurisy” OR “acute respiratory distress syndrome” OR “pleurisy” OR “pulmonary fibrosis” OR “lung abscess”))
Gastroenterology	(TS=(“gastroenter*” OR “gastrointestinal*” OR “digestive*” OR “urogenital*” OR “oesophag*” OR “hepatobili*” OR “pancrea*” OR “hepat*” OR “biliary*”

	OR “stomach*” OR “intestine*” OR “bowel*” OR “cholecyst*” OR “gastroesophageal reflux disease*” OR “peptic ulcer disease” OR “gastr*” OR “Crohn's disease” OR “liver cirrhosis” OR “fatty liver disease” OR “biliary obstruction”) OR TI=(“gastroenter*” OR “gastrointestinal*” OR “digestive*” OR “urogenital*” OR “oesophag*” OR “hepatobili*” OR “pancrea*” OR “hepat*” OR “biliary*” OR “stomach*” OR “intestine*” OR “bowel*” OR “cholecyst*” OR “gastroesophageal reflux disease*” OR “peptic ulcer disease” OR “gastr*” OR “Crohn's disease” OR “liver cirrhosis” OR “fatty liver disease” OR “biliary obstruction”) OR AB=(“gastroenter*” OR “gastrointestinal*” OR “digestive*” OR “urogenital*” OR “oesophag*” OR “hepatobili*” OR “pancrea*” OR “hepat*” OR “biliary*” OR “stomach*” OR “intestine*” OR “bowel*” OR “cholecyst*” OR “gastroesophageal reflux disease*” OR “peptic ulcer disease” OR “gastr*” OR “Crohn's disease” OR “liver cirrhosis” OR “fatty liver disease” OR “biliary obstruction”))
Urology & Male Reproductive System	(TS=(“urolog*” OR “genitourinary*” OR “urinary*” OR “urogenital*” OR “renal*” OR “nephrolog*” OR “kidney*” OR “bladder*” OR “ureter*” OR “urethra*” OR “testis*” OR “testic*” OR “prostat*” OR “penis” OR “epididymi*” OR “erectile dysfunction”) OR TI=(“urolog*” OR “genitourinary*” OR “urinary*” OR “urogenital*” OR “renal*” OR “nephrolog*” OR “kidney*” OR “bladder*” OR “ureter*” OR “urethra*” OR “testis*” OR “testic*” OR “prostat*” OR “penis” OR “epididymi*” OR “erectile dysfunction”) OR AB=(“urolog*” OR “genitourinary*” OR “urinary*” OR “urogenital*” OR “renal*” OR “nephrolog*” OR “kidney*” OR “bladder*” OR “ureter*” OR “urethra*” OR “testis*” OR “testic*” OR “prostat*” OR “penis” OR “epididymi*” OR “erectile dysfunction”))
Gynecology & Obstetrics	(TS=(“gynecolog*” OR “obstetric*” OR “digestive*” OR “women's reproductive system” OR “uterus*” OR “ovar*” OR “oviduct*” OR “cervix uteri*” OR “cervical*” OR “vagina*” OR “endometriosis*” OR “polycystic ovary syndrome” OR “uterine fibroid*” OR “menstrual*” OR “menstruat*” OR “dysmenorrhea*” OR “amenorrhea” OR “endometrial*” OR “pregnant*” OR “pregnancy” OR “infertility” OR ” eclampsia” OR “placenta previa” OR “amniotic*” OR “postpartum hemorrhage” OR “misbirth*”) OR TI=(“gynecolog*” OR “obstetric*” OR “digestive*” OR “women's reproductive system” OR “uterus*” OR “ovar*” OR “oviduct*” OR “cervix uteri*” OR “cervical*” OR “vagina*” OR “endometriosis*” OR “polycystic ovary syndrome” OR “uterine fibroid*” OR “menstrual*” OR “menstruat*” OR “dysmenorrhea*” OR “amenorrhea” OR “endometrial*” OR “pregnant*” OR “pregnancy” OR “infertility” OR ” eclampsia” OR “placenta previa” OR “amniotic*” OR “postpartum hemorrhage” OR “misbirth*”) OR AB=(“gynecolog*” OR “obstetric*” OR “digestive*” OR “women's reproductive system” OR “uterus*” OR “ovar*” OR “oviduct*” OR “cervix uteri*” OR “cervical*” OR “vagina*” OR “endometriosis*” OR “polycystic ovary syndrome” OR “uterine fibroid*” OR “menstrual*” OR “menstruat*” OR “dysmenorrhea*” OR “amenorrhea” OR “endometrial*” OR “pregnant*” OR “pregnancy” OR “infertility” OR ” eclampsia” OR “placenta previa” OR “amniotic*” OR “postpartum hemorrhage” OR “misbirth*”))
Pediatrics	(TS=(“pediatric*” OR “child health*” OR “children health*” OR “children disease*” OR “disease of child*” OR “disease of newborn*” OR “newborn health*” OR “neonatal health*” OR “neonatal disease*” OR “infantile pneumonia*” OR “infantile asthma*” OR “infantile diarrhea*” OR “hand-foot-mouth disease in child*” OR “chickenpox in child*” OR “measles in child*” OR “mumps in child*” OR “rubella in child*” OR “scarlet fever in child*” OR “rotavirus infection in child*” OR “Kawasaki disease*”) OR TI=(“pediatric*” OR “child health*” OR “children health*” OR “children disease*” OR “disease of child*” OR “disease of newborn*” OR “newborn health*” OR “neonatal health*” OR “neonatal disease*” OR “infantile pneumonia*” OR “infantile asthma*” OR “infantile diarrhea*” OR “hand-foot-mouth disease in child*” OR “chickenpox in child*” OR “measles in child*” OR “mumps in child*” OR “rubella in child*” OR “scarlet fever in child*” OR “rotavirus infection in child*” OR “Kawasaki disease*”) OR AB=(“pediatric*” OR “child health*” OR “children health*” OR

	“children disease*” OR “disease of child*” OR “disease of newborn*” OR “newborn health*” OR “neonatal health*” OR “neonatal disease*” OR “infantile pneumonia*” OR “infantile asthma*” OR “infantile diarrhea*” OR “hand-foot-mouth disease in child*” OR “chickenpox in child*” OR “measles in child*” OR “mumps in child*” OR “rubella in child*” OR “scarlet fever in child*” OR “rotavirus infection in child*” OR “Kawasaki disease*”))
Psychiatry & Mental health	(TS=(“psychiatri*” OR “mental health*” OR “emotional well-being*” OR “psychological health*” OR “depressive disorder*” OR “bipolar disorder*” OR “anxiety disorder*” OR “schizophrenia*” OR “obsessive-compulsive disorder*” OR “post-traumatic stress disorder*” OR “attention-deficit/hyperactivity disorder*” OR “autism spectrum disorder*” OR “sleep disorder*” OR “personality disorders*”) OR TI=(“psychiatri*” OR “mental health*” OR “emotional well-being*” OR “psychological health*” OR “depressive disorder*” OR “bipolar disorder*” OR “anxiety disorder*” OR “schizophrenia*” OR “obsessive-compulsive disorder*” OR “post-traumatic stress disorder*” OR “attention-deficit/hyperactivity disorder*” OR “autism spectrum disorder*” OR “sleep disorder*” OR “personality disorders*”) OR AB=(“psychiatri*” OR “mental health*” OR “emotional well-being*” OR “psychological health*” OR “depressive disorder*” OR “bipolar disorder*” OR “anxiety disorder*” OR “schizophrenia*” OR “obsessive-compulsive disorder*” OR “post-traumatic stress disorder*” OR “attention-deficit/hyperactivity disorder*” OR “autism spectrum disorder*” OR “sleep disorder*” OR “personality disorders*”))
Neurology	(TS=(“neurolog*” OR “nervous system *” OR “neurosurgery *” OR “neuropathy*” OR “cerebral disease*” OR “brain disease*” OR “myelopathy” OR “epilepsy” OR “cerebrovascular disease*” OR “cerebral stroke” OR “Parkinson's disease” OR “Alzheimer's disease” OR “Multiple sclerosis*” OR “Migraine*” OR “Amyotrophic lateral sclerosis” OR “Huntington's disease” OR “traumatic brain injury” OR “spinal cord injury” OR “Tourette syndrome” OR “Guillain-Barré syndrome” OR “Restless legs syndrome” OR “facial paralysis” OR “myasthenia gravis*” OR “trigeminal neuralgia*”) OR TI=(“neurolog*” OR “nervous system *” OR “neurosurgery *” OR “neuropathy*” OR “cerebral disease*” OR “brain disease*” OR “myelopathy” OR “epilepsy” OR “cerebrovascular disease*” OR “cerebral stroke” OR “Parkinson's disease” OR “Alzheimer's disease” OR “Multiple sclerosis*” OR “Migraine*” OR “Amyotrophic lateral sclerosis” OR “Huntington's disease” OR “traumatic brain injury” OR “spinal cord injury” OR “Tourette syndrome” OR “Guillain-Barré syndrome” OR “Restless legs syndrome” OR “facial paralysis” OR “myasthenia gravis*” OR “trigeminal neuralgia*”))
Musculoskeletal & Connective tissue disease	(TS=(“musculoskeletal*” OR “muscul*” OR “skeletal*” OR “connective tissue diseases*” OR “rheumatology*” OR “rheumatic*” OR “bone and joint” OR “arthriti*” OR “cartilage*” OR “cartilaginous*” OR “bone fractures” OR “scoliosis” OR “osteo*” OR “ankylosing spondylitis*” OR “herniated disc” OR “tendinitis” OR “myositis” OR “myalgia” OR “systemic lupus erythematosus” OR “Sjögren's syndrome”) OR TI=(“musculoskeletal*” OR “muscul*” OR “skeletal*” OR “connective tissue diseases*” OR “rheumatology*” OR “rheumatic*” OR “bone and joint” OR “arthriti*” OR “cartilage*” OR “cartilaginous*” OR “bone fractures” OR “scoliosis” OR “osteo*” OR “ankylosing spondylitis*” OR “herniated disc” OR “tendinitis” OR “myositis” OR “myalgia” OR “systemic lupus erythematosus” OR “Sjögren's syndrome”) OR AB=(“musculoskeletal*” OR “muscul*” OR “skeletal*” OR “connective tissue diseases*” OR “rheumatology*” OR “rheumatic*” OR “bone and joint” OR “arthriti*” OR “cartilage*” OR “cartilaginous*” OR “bone fractures” OR “scoliosis” OR “osteo*” OR “ankylosing spondylitis*” OR “herniated disc” OR “tendinitis” OR “myositis” OR “myalgia” OR “systemic lupus erythematosus” OR “Sjögren's syndrome”

	syndrome”))
Oncology	(TS=(“cancer” OR “oncology” OR “tumor” OR “phymatology” OR “carcinoma”) OR TI=(“cancer” OR “oncology” OR “tumor” OR “phymatology” OR “carcinoma”) OR AB=(“cancer” OR “oncology” OR “tumor” OR “phymatology” OR “carcinoma”))
Ophthalmology*	(TS=(“eye*” OR “ocular*” OR “ophthal*” OR "eye disease*" OR "eye disorder*" OR “eye injur*” OR “amblyopia” OR "ametropia" OR “anisocoria” OR "anophthalmia" OR “blind*” OR “cataract*” OR “cornea*” OR “conjunctiva*” OR “conjunctivitis” “choroid*” OR “eyelid*” OR “extraocular muscle*” OR “glaucoma*” OR “kerato*” OR “keratitis” OR “macula*” OR “optic*” OR “retin*” OR "refractive disorder*" OR “refractive error*” OR “strabismus” OR “trachoma*” OR “vision care” OR “vision defect*” OR “vision disorder*” OR “vision health” OR “vision loss” OR “vision screen*” OR “impaired vision” OR “visual care” OR “visual defect*” OR “visual disorder*” OR “visual health” OR “visual loss” OR “vision screen*” OR “visual impair*”) OR TI=(“eye*” OR “ocular*” OR “ophthal*” OR "eye disease*" OR "eye disorder*" OR “eye injur*” OR “amblyopia” OR "ametropia" OR “anisocoria” OR "anophthalmia" OR “blind*” OR “cataract*” OR “cornea*” OR “conjunctiva*” OR “conjunctivitis” “choroid*” OR “eyelid*” OR “extraocular muscle*” OR “glaucoma*” OR “kerato*” OR “keratitis” OR “macula*” OR “optic*” OR “retin*” OR "refractive disorder*" OR “refractive error*” OR “strabismus” OR “trachoma*” OR “vision care” OR “vision defect*” OR “vision disorder*” OR “vision health” OR “vision loss” OR “vision screen*” OR “impaired vision” OR “visual care” OR “visual defect*” OR “visual disorder*” OR “visual health” OR “visual loss” OR “vision screen*” OR “visual impair*”) OR AB=(“eye*” OR “ocular*” OR “ophthal*” OR "eye disease*" OR "eye disorder*" OR “eye injur*” OR “amblyopia” OR "ametropia" OR “anisocoria” OR "anophthalmia" OR “blind*” OR “cataract*” OR “cornea*” OR “conjunctiva*” OR “conjunctivitis” “choroid*” OR “eyelid*” OR “extraocular muscle*” OR “glaucoma*” OR “kerato*” OR “keratitis” OR “macula*” OR “optic*” OR “retin*” OR "refractive disorder*" OR “refractive error*” OR “strabismus” OR “trachoma*” OR “vision care” OR “vision defect*” OR “vision disorder*” OR “vision health” OR “vision loss” OR “vision screen*” OR “impaired vision” OR “visual care” OR “visual defect*” OR “visual disorder*” OR “visual health” OR “visual loss” OR “vision screen*” OR “visual impair*”))
Dermatology	(TS=(“dermatolog*” OR “cutaneous*” OR “skin disease*” OR “skin health*” OR “skin disorder*” OR “acne” OR “eczema” OR “psoriasis” OR “dermatitis*” OR “rosacea” OR “urticaria” OR “vitiligo” OR “tinea *” OR “warts*” OR “herpes” OR “scabies” OR “dermatocellulitis” OR “furuncle” OR “shingles” OR “keratosis*”) OR TI=(“dermatolog*” OR “cutaneous*” OR “skin disease*” OR “skin health*” OR “skin disorder*” OR “acne” OR “eczema” OR “psoriasis” OR “dermatitis*” OR “rosacea” OR “urticaria” OR “vitiligo” OR “tinea *” OR “warts*” OR “herpes” OR “scabies” OR “dermatocellulitis” OR “furuncle” OR “shingles” OR “keratosis*”) OR AB=(“dermatolog*” OR “cutaneous*” OR “skin disease*” OR “skin health*” OR “skin disorder*” OR “acne” OR “eczema” OR “psoriasis” OR “dermatitis*” OR “rosacea” OR “urticaria” OR “vitiligo” OR “tinea *” OR “warts*” OR “herpes” OR “scabies” OR “dermatocellulitis” OR “furuncle” OR “shingles” OR “keratosis*”))
Otolaryngology	(TS=(“otolaryngolog*” OR “otorhinolaryngolog*” OR “ear disease*” OR “nasal disease*” OR “throat disease*” OR “otolog*” OR “rhinolog*” OR “laryngolog*” OR “pharyngolog*” OR “audiolog*” OR “osphresiolog*” OR “otitis*” OR “sinusitis*” OR “rhinitis*” OR “pharyngitis*” OR “laryngitis” OR “hearing loss” OR “tinnitus*” OR “Meniere's disease” OR “epistaxis” OR “nasal polyps” OR “deviated septum” OR “hoarseness” OR “sleep apnea hypopnea syndrome”) OR TI=(“otolaryngolog*” OR “otorhinolaryngolog*” OR “ear disease*” OR “nasal disease*” OR “throat disease*” OR “otolog*” OR “rhinolog*” OR “laryngolog*” OR “pharyngolog*” OR “audiolog*” OR “osphresiolog*” OR “otitis*” OR “sinusitis*” OR “rhinitis*” OR “pharyngitis*” OR “laryngitis” OR “hearing loss” OR “tinnitus*” OR “Meniere's disease” OR “epistaxis” OR “nasal polyps” OR “deviated septum” OR “hoarseness” OR “sleep apnea

	hypopnea syndrome”) OR AB=(“otolaryngolog*” OR “otorhinolaryngolog*” OR “ear disease*” OR “nasal disease*” OR “throat disease*” OR “otolog*” OR “rhinolog*” OR “laryngolog*” OR “pharyngolog*” OR “audiolog*” OR “osphresiology*” OR “otitis*” OR “sinusitis*” OR “rhinitis*” OR “pharyngitis*” OR “laryngitis*” OR “hearing loss” OR “tinnitus*” OR “Meniere's disease” OR “epistaxis” OR “nasal polyps” OR “deviated septum” OR “hoarseness” OR “sleep apnea hypopnea syndrome”))
Endocrinology	(TS=(“endocrin*” OR “hormone disorder*” OR “adrenal disease*” OR “pituitary disease*” OR “parathyroid disease*” OR “thyroid disease*” OR “diabet*” OR “hypothyroid*” OR “hyperthyroid*” OR “Graves' disease*” OR “Hashimoto's thyroiditis” OR “Addison's disease” OR “Cushing's syndrome” OR “hyperparathyroid*” OR “hypoparathyroid*” OR “pheochromocytoma” OR “hyperaldosteron*” OR “hyperprolactinem*” OR “hypopituitarism” OR “gigantism” OR “dwarfism” OR “hypoglycemia”) OR TI=(“endocrin*” OR “hormone disorder*” OR “adrenal disease*” OR “pituitary disease*” OR “parathyroid disease*” OR “thyroid disease*” OR “diabet*” OR “hypothyroid*” OR “hyperthyroid*” OR “Graves' disease*” OR “Hashimoto's thyroiditis” OR “Addison's disease” OR “Cushing's syndrome” OR “hyperparathyroid*” OR “hypoparathyroid*” OR “pheochromocytoma” OR “hyperaldosteron*” OR “hyperprolactinem*” OR “hypopituitarism” OR “gigantism” OR “dwarfism” OR “hypoglycemia”) OR AB=(“endocrin*” OR “hormone disorder*” OR “adrenal disease*” OR “pituitary disease*” OR “parathyroid disease*” OR “thyroid disease*” OR “diabet*” OR “hypothyroid*” OR “hyperthyroid*” OR “Graves' disease*” OR “Hashimoto's thyroiditis” OR “Addison's disease” OR “Cushing's syndrome” OR “hyperparathyroid*” OR “hypoparathyroid*” OR “pheochromocytoma” OR “hyperaldosteron*” OR “hyperprolactinem*” OR “hypopituitarism” OR “gigantism” OR “dwarfism” OR “hypoglycemia”))
Hematology & Lymphatic system	(TS=(“hematolog*” OR “lymphatic disease*” OR “blood disease*” OR “anemia” OR “leukemi*” OR “lymphoma*” OR “hemophilia” OR “thalassemia” OR “hyperthyroid*” OR “Sickle cell disease” OR “idiopathic thrombocytopenic purpura” OR “hemochromatosis” OR “myelodysplastic syndromes” OR “aplastic anemia” OR “disseminated intravascular coagulation” OR “thrombocythaemia” OR “thrombocytopenia” OR “multiple myeloma*”) OR TI=(“hematolog*” OR “lymphatic disease*” OR “blood disease*” OR “anemia” OR “leukemi*” OR “lymphoma*” OR “hemophilia” OR “thalassemia” OR “hyperthyroid*” OR “Sickle cell disease” OR “idiopathic thrombocytopenic purpura” OR “hemochromatosis” OR “myelodysplastic syndromes” OR “aplastic anemia” OR “disseminated intravascular coagulation” OR “thrombocythaemia” OR “thrombocytopenia” OR “multiple myeloma*”) OR AB=(“hematolog*” OR “lymphatic disease*” OR “blood disease*” OR “anemia” OR “leukemi*” OR “lymphoma*” OR “hemophilia” OR “thalassemia” OR “hyperthyroid*” OR “Sickle cell disease” OR “idiopathic thrombocytopenic purpura” OR “hemochromatosis” OR “myelodysplastic syndromes” OR “aplastic anemia” OR “disseminated intravascular coagulation” OR “thrombocythaemia” OR “thrombocytopenia” OR “multiple myeloma*”))
Year Published*	2000 -2023.6.15
Language*	English
Document Type*	DT=(Article OR Review)

*In Scopus database, the same search terms were used.

Supplementary Table 3. Total Number and Annual Trends of Documents focusing on AI Ethics in Medicine and Its Sub-disciplines (Database: WOSCC).

Disciplines	Total	Year																							
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023*
Medicine & Health	8345	4	2	5	4	6	10	11	9	15	15	22	19	32	56	65	65	70	125	241	519	1105	1845	2465	1635
Oncology	1143	0	0	1	1	2	1	3	3	3	4	3	11	10	16	12	17	17	20	44	77	156	235	299	208
Ophthalmology	1082	0	2	3	0	0	1	2	4	6	8	7	3	9	7	17	15	11	25	54	77	155	222	302	152
Cardiovasology	447	0	0	0	0	0	0	0	0	1	0	0	0	2	2	3	3	3	9	10	40	57	99	145	73
Respirology	440	1	0	1	0	1	1	0	0	1	0	1	1	0	1	3	4	4	5	7	17	65	130	129	68
Psychiatry & Mental health	422	1	0	0	0	0	0	0	0	0	0	0	0	1	2	4	1	2	9	14	28	67	90	131	72
Neurology	374	1	0	1	0	0	0	0	3	1	3	3	2	8	1	8	5	7	14	14	24	54	60	102	63
Urology & Male Reproductive System	358	0	0	1	0	0	0	3	2	0	4	5	9	11	10	5	11	6	11	18	28	43	78	64	49
Endocrinology	308	0	0	0	1	0	0	0	0	1	1	2	2	0	1	1	1	2	3	9	21	49	80	82	52
Gastroenterology	259	0	0	0	0	1	1	0	1	0	2	2	4	1	10	2	8	4	6	8	22	50	48	62	27
Gynecology & Obstetrics	201	0	0	0	0	0	1	1	0	0	1	1	2	2	5	2	4	1	4	8	13	24	40	50	42
Musculoskeletal & Connective tissue disease	172	1	0	0	0	1	0	1	1	0	2	2	1	2	4	3	4	4	10	4	9	30	26	44	23
Dermatology	91	0	0	0	0	0	0	0	0	0	1	0	0	2	0	1	1	1	0	5	2	14	23	28	13
Pediatrics	90	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	2	4	9	13	21	22	15
Hematology & Lymphatic system	69	0	0	0	0	1	0	1	1	2	0	0	0	0	0	1	0	0	2	4	2	11	11	14	19
Otolaryngology	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	6	5	5

*Data for 2023 was as of 15 July 2023, sourced from WOSCC.

Supplementary Table 4. Top 10 high cited documents focusing on the ethics of AI in ophthalmology.

Ranking	Title	Citations,n	The first author	Year	Source	DOI
1	Identifying Medical Diagnoses and Treatable Diseases by Image-Based Deep Learning	1395	Kermany, DS	2018	CELL	10.1016/j.cell.2018.02.010
2	Automated Identification of Diabetic Retinopathy Using Deep Learning	646	Gargeya, R	2017	OPHTHALMOLOGY	10.1016/j.ophtha.2017.02.008
3	Artificial intelligence and deep learning in ophthalmology	463	Ting, DSW	2019	BRITISH JOURNAL OF OPTHALMOLOGY	10.1136/bjophthalmol-2018-313173
4	A cross-modality learning approach for vessel segmentation in retinal images	408	Li, QL	2016	IEEE TRANSACTIONS ON MEDICAL IMAGING	10.1109/TMI.2015.2457891
5	Automatic detection of red lesions in digital color fundus photograph	365	Niemeijer, M	2005	IEEE TRANSACTIONS ON MEDICAL IMAGING	10.1109/TMI.2005.843738
6	Artificial intelligence in retina	348	Schmidt-Erfurth, U	2018	PROGRESS IN RETINAL AND EYE RESEARCH	10.1016/j.preteyeres.2018.07.004
7	The Lancet Global Health Commission on Global Eye Health: vision beyond 2020	284	Burton, MJ	2021	LANCET GLOBAL HEALTH	10.1016/S2214-109X(20)30488-5
8	A feature-based, robust, hierarchical algorithm for registering pairs of images of the curved human retina	251	Can, A	2002	IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE	10.1109/34.990136
9	Deep image mining for diabetic retinopathy screening	248	Quellec, G	2017	MEDICAL IMAGE ANALYSIS	10.1016/j.media.2017.04.012
10	Deep convolution neural network for accurate diagnosis of glaucoma using digital fundus images	240	Raghavendra, U	2018	INFORMATION SCIENCES	10.1016/j.ins.2018.01.051

Ranking: based on total citation numbers. Citations as of 15 July 2023 from WOSCC

Supplementary Table 5. Top 10 countries in terms of number of documents focusing on the ethics of AI in ophthalmology.

Ranking	Countries	Publications, n	Citations, n	H-index	Co-author countries	Total co-author frequency
1	USA	145	6289	31	50	158
2	CHINA	138	3674	23	36	112
3	UK	71	2552	21	43	120
4	INDIA	63	1535	13	41	79
5	SINGAPORE	30	1748	17	38	89
6	AUSTRALIA	30	1057	15	38	75
7	SOUTH KOREA	27	460	12	13	20
8	SAUDI ARABIA	20	345	8	11	20
9	CANADA	18	302	8	17	29
10	GERMANY	17	2298	11	31	49
10	JAPAN	17	376	8	18	30
10	SWITZERLAND	17	638	10	36	68

Ranking: based on total publication numbers. Publications, H-index and Citations as of 15 July 2023 from WOSCC.

Supplementary Table 6. Top 10 institutions in terms of number of documents focusing on the ethics of AI in ophthalmology.

Ranking	Institutions	Country	Publications, n
1	UCL	UK	34
2	Moorfields Eye Hosp	UK	30
3	Natl Univ Singapore	Singapore	25
4	Singapore Natl Eye Ctr	Singapore	24
5	Sun Yat Sen Univ	People's Republic of China	19
6	Johns Hopkins Univ	US	15
7	Univ of Calif System	US	14
8	Stanford Univ	US	13
9	Harvard Univ	US	12
10	Zhejiang Univ	People's Republic of China	12

Ranking: based on total publication numbers. Publications as of 15 July 2023 from WOSCC.

Supplementary Table 7. Top 10 scholars in terms of number of documents focusing on the ethics of AI in ophthalmology.

Ranking	Author	Countries	Publications, n	H-index	Main areas
1	Keane, Pearse A	UK	13	50	Retinal imaging; Retinal disease algorithms; Clinical applications of multiple eye disease algorithms and their ethics
2	Ting, Daniel S W	Singapore	11	39	AI and big data analytics for multiple eye diseases; Remote application of ophthalmic AI; Application of privacy-preserving technologies such as IoT/blockchain/GANs in ophthalmic artificial intelligence
3	Lin, Haotian	People's Republic of China	8	27	Prevention and treatment of blinding eye diseases; Research and development of ophthalmic artificial intelligence diagnosis and treatment technology; Medical big data application and regulatory
4	Balaskas, Konstantinos	UK	7	22	AI for multiple retinal diseases; Clinical applications and ethics of ophthalmic telemedicine and algorithms
5	Cheung, Carol Y	People's Republic of China	7	61	Development and application of AI for glaucoma, retinal diseases and Alzheimer's disease Clinical screening and diagnostic applications of AI in ophthalmology
6	Wong, Tien Yin	People's Republic of China	7	159	Epidemiological studies and real-world applications of algorithms in retinal diseases and ocular imaging
7	Abramoff, Michael D	US	6	56	Autonomous AI development for diabetic retinopathy; Morals and Ethics of Autonomous AI in Ophthalmology
8	Lee, Aaron Y	US	6	32	Ophthalmic image standardization; Privacy protection and development of interpretable ophthalmic AI technology; Integration and clinical application of ophthalmic AI
9	Schmidt-erfurth, Ursula	Austria	6	79	Development and clinical application of AI for diagnosis and analysis of retinal images
10	Sznitman, Raphael	Switzerland	6	19	Development and application of medical image-based AI algorithms and robots

Ranking: based on total publication numbers. Publications and H-index as of 15 July 2023 from WOSCC.

Supplementary Table 8. Top 10 funding sources in terms of number of documents focusing on the ethics of AI in ophthalmology.

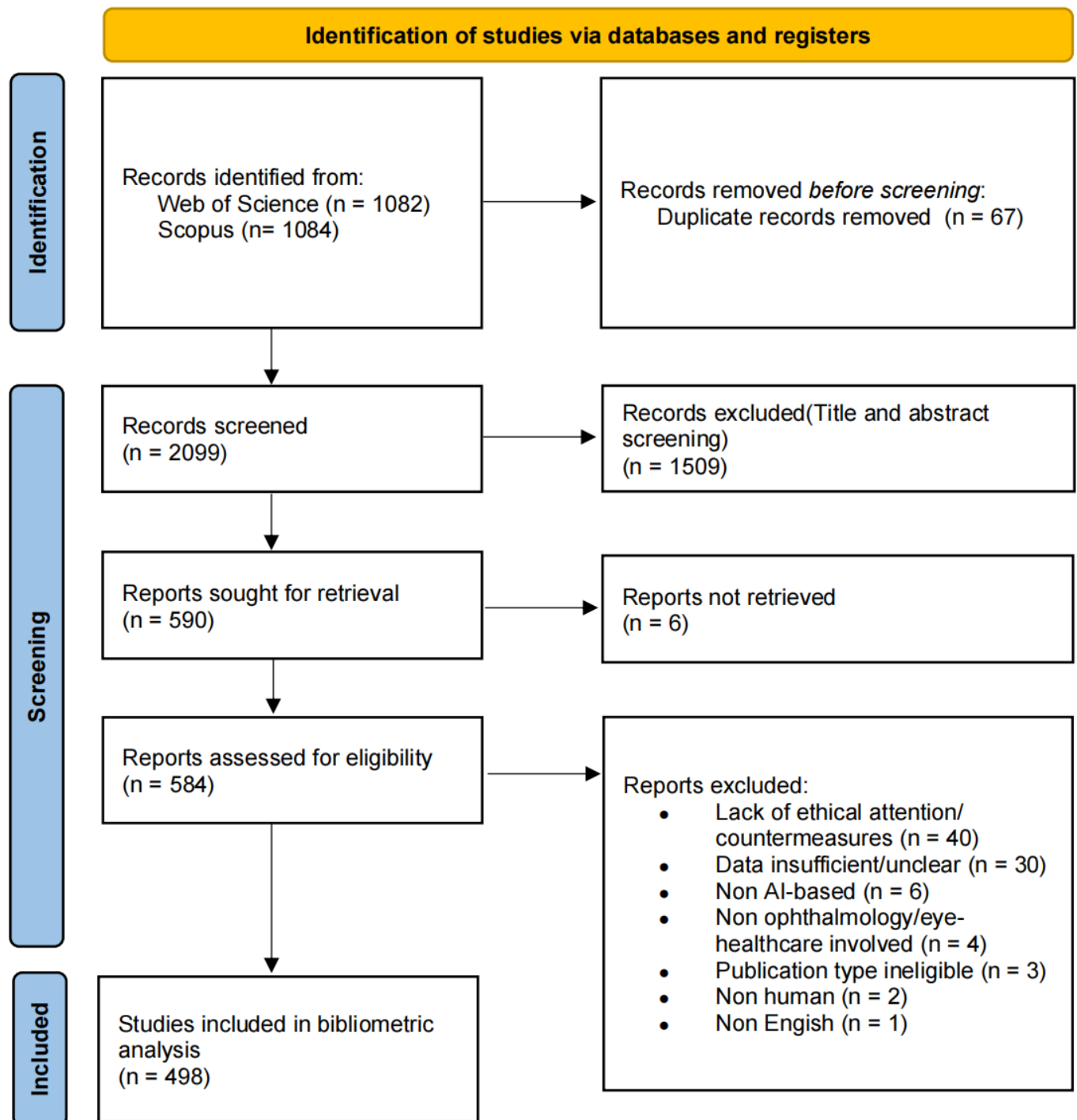
Ranking	Funding Agencies	Publications,n	Countries
1	National Natural Science Foundation of China (NSFC)	66	People's Republic of China
2	United States Department of Health & Human Services	52	US
3	National Institutes of Health (NIH) - USA	52	US
4	Research to Prevent Blindness (RPB)	33	US
5	UK Research & Innovation (UKRI)	25	UK
6	Medical Research Council UK (MRC)	15	UK
7	National Science Foundation (NSF)	15	US
8	NIH National Eye Institute (NEI)	15	US
9	National Key R&D Program of China	13	People's Republic of China
10	National Research Foundation of Korea	13	South Korea

Ranking: based on total publication numbers. Publications and H-index as of 15 July 2023 from WOSCC.

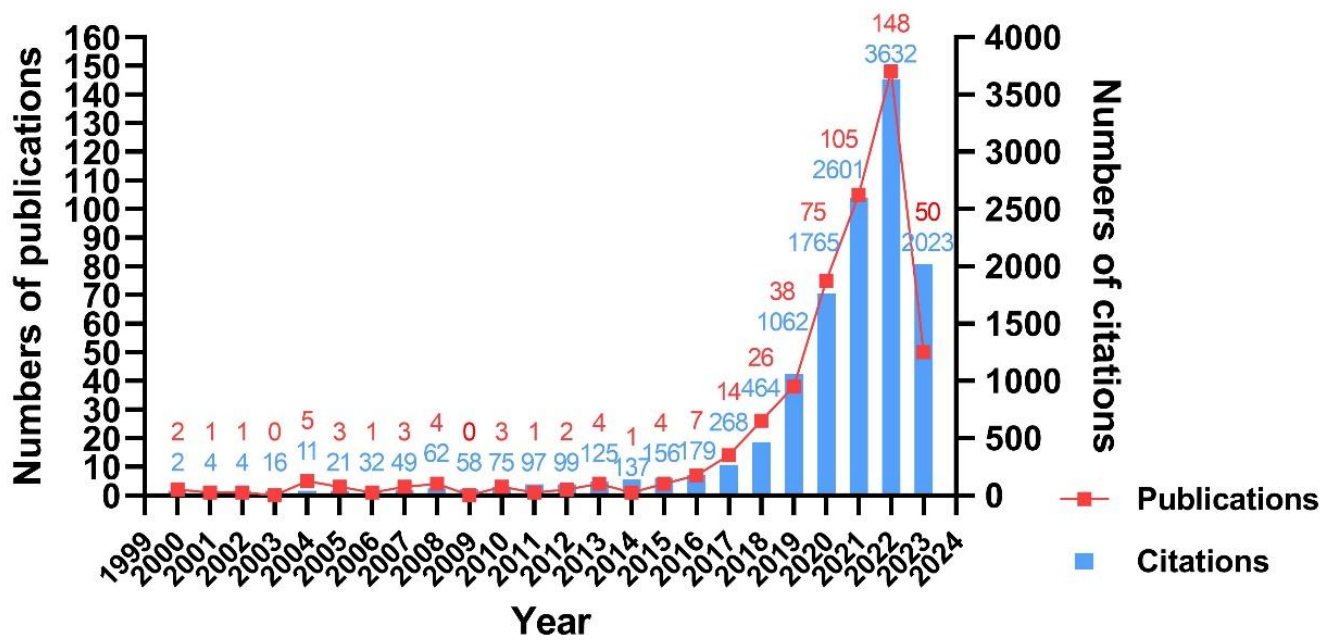
Supplementary Table 9. Ethical Themes and Associated Terms.

Ethical Themes (Variables)	Terms
Transparency & Interpretability	Transparency, explainability, explicability, understandability, interpretability
Justice & Fairness	Justice, fairness, equity, (non-)bias, (non-)discrimination, diversity, plurality, accessibility, remedy, redress, access and distribution
Responsibility & Accountability	Responsibility, accountability, liability, acting with integrity
Privacy & Data security	Security, data management, confidentiality, privacy, personal or private information
Non-maleficence & Beneficence	Non-maleficence, harm, protection, precaution, prevention, integrity (bodily or mental), non-subversion, benefits, safety beneficence, well-being, peace, social good, common good
Autonomy & Dignity	Autonomy, dignity, consent, choice, self-determination, liberty, empowerment
Trust, Reliability & Robustness	Trust, reliability, confidence, reliance, trustworthiness, credibility, dependability, robustness
Solidarity	Solidarity, cohesion
Sustainability	Sustainability, environment (nature), energy, resources (energy)

Supplementary Figure 1. PRISMA Flow Diagram.



Supplementary Figure 2. Annual trends of publications and citations focusing on the ethics of AI in ophthalmology.



a

N. publications

- 100+
- 50-100
- 30-50
- 10-30
- 1-10

— Co-authorship

b

Circle: Institution
N. publications

- 35
- 25
- 15
- 5

Line: Co-authorship

c

Circle: Author
N. publications

- 15
- 10
- 5

Line: Co-authorship

Supplementary Note 1. Synonyms merged in VOSviewer.

Here, the original text content used for merging synonyms in VOSviewer are displayed.

1. For countries:

label replace by

scotland uk

england uk

wales uk

north ireland uk

taiwan peoples r china

2. For institutions:

label replace by

ucl inst ophthalmol ucl

moorfields eye hosp nhs fdn trust moorfields eye hosp

singapore eye res inst singapore natl eye ctr

natl univ singapore hosp natl univ singapore

sun yet sen univ sun yat sen univ

univ calif univ calif sytem

univ calif los angeles univ calif sytem

univ calif irvine univ calif sytem

univ calif san diego univ calif sytem

univ calif san diego ucsd univ calif sytem

univ calif san franciscouniv calif sytem

3. For authors(scholars):

label replace by

ting, daniel shu wei ting, daniel s. w.

cheung, carol y. y. cheung, carol y.

4. For terms:

label replace by

ai system artificial intelligence

cnn convolutional neural network

gans generative adversarial network

gan generative adversarial network

blockchain blockchain technology

color fundus image color fundus photograph

diabetes patient diabetic patient

dr screening diabetic retinopathy screening

diabete diabetes

dme diabetic macular edema

fundus photograph fundus photography

fundus image fundus photography

fundus images fundus photography

machine learning model machine learning

ml algorithm machine learning

optical coherence tomography a optical coherence tomography

optical coherence tomography image optical coherence tomography

oct scan optical coherence tomography

oct optical coherence tomography

privacy concern privacy

privacy issue privacy

retinal blood vessel retinal vessel

roc curve roc

svm support vector machine

segment segmentation